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## The Hip – from Cradle to Grave

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### Abstract

From a dissertation read before the Society on Friday, 26th November, 1965

From birth to old age the hip joint provides a fascinating spectrum of disease processes; this provides a useful starting point for a study of the interaction of development of structure with development of function and the pathological variants of this interaction. Because of limitations of space only a few disease processes will be chosen and much of the review will be devoted to normal structure and function.

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# THE HIP - FROM CRADLE TO GRAVE

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From birth to old age the hip joint provides a fascinating spectrum of disease processes; this provides a useful starting point for a study of the interaction of development of structure with development of function and the pathological variants of this interaction. Because of limitations of space only a few disease processes will be chosen and much of the review will be devoted to normal structure and function.

## ANATOMY

The general anatomy of the adult hip joint is well known and will therefore only be briefly mentioned. It is a synovial ball and socket joint in which the almost spherical head of the femur sits in the deep cup of the acetabulum, the two

apposed surfaces being almost congruent. The neck of the femur is angulated medially on the shaft at an angle of  $135^\circ$  and is anteverted  $25^\circ$  at birth.

The anatomy of the blood supply is important both during development and later life. The arterial supply is from two main sources in the adult; the artery of the ligamentum teres and the retinacular vessels which ascend the neck of the femur in the fibres of the joint capsule, entering the synovial cavity at the upper part of the neck. The relative importance of these vessels varies greatly during development; the following table attempts to show which vessels are responsible for supply at each age:—

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Retinacular vessels — Posterolateral — Superior Metaphyseal; Lateral Epiphyseal.		
Posteromedial — Inferior Metaphyseal.		
Age	Vessels	
Foetal — 4 months .....	Lat. epiphyseal Inf. metaphyseal Artery of lig. teres	All are end arteries
4 months — 4 years .....	Transitional period	
4 years — 9 years .....	Lateral epiphyseal	
7 years — 10 years .....	Transitional period	
10 years — Maturity .....	Lateral epiphyseal Artery of lig. teres	Anastomoses begin Anastomoses across epiphyseal line

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After maturity has been reached all the vessels take part in the supply but the relative importance of each is disputed; the artery of the ligamentum teres has been said to be capable of supplying the whole head (Waldenstrom 1934, Wolcott 1943.) Strange (1965) believes that this would be possible in only 20% of the population; in a further 20% he suggests that it has no function and in 60% its supply is restricted to 10% of the head. Likewise the contribution of the Nutrient artery of the femur has been variously assessed: Tucker (1949) and Trueta and Harrison (1953) do not believe that it has any role in supplying the head.

Racial variations occur especially with respect to the importance of the artery of the ligamentum teres in the negroid, the supply being much greater in the 4 - 9 years period.

The importance of these facts should become more apparent on considering pathological processes later in the review.

#### PHYSIOLOGY

The articular surfaces of the joint are of hyaline cartilage which, in spite of its name, has strands of collagen running in a basket work fashion, serving to prevent lateral expansion as a result of vertical compression. The load on these surfaces is high and thus perfect distribution is required, as is a low coefficient of friction. The coefficient of friction has been calculated by many people with results ranging from 0.0075 to 0.023; the average of Charnley's experiments was 0.013. This compares with 0.03 for ice on ice and 0.1 for mechanical ball bearings.

In spite of this low coefficient of friction the movement of the surfaces, one over the other, produces continual abrasion of surface layers — this may be considered as wear and tear or simply as replacement; the result appears to be the same. The other important effect which movement has, is the compression and expansion of the cartilage and this may be important in lubrication, the synovial fluid entering and leaving the cartilage as it would a sponge. The flow of fluid in and out of the cartilage may also be important to the nutrition of the avascular tissue.

The lubrication has been thought to occur in many different ways; a combination of several would seem to be possible. A hydrodynamic method in which one surface floats on a film of fluid on the other surface is the simplest, but Tanner (1949) believed that the nature of the fluid precludes this under the

conditions existing in the hip joint. A refinement of this has been suggested by Charnley (1959) who favours a form of boundary lubrication; in this form the lubricant fluid has an affinity for both surfaces enabling a thin film of fluid to be present even at high pressures. A further refinement combines all that has so far been described with the expression of the fluid from the cartilage under pressure.

The viscosity of the fluid itself may be important in that the extent of polymerisation is reduced in several diseases of the hip joint (Matsunaga, Ioki and Aoki 1958). Depolymerisation is associated with decreased viscosity.

Many of the disease processes of the hip involve physical displacement of one form on another and hence a brief consideration of the forces acting on the joint is essential. When a person is standing on both legs the weight on each joint is half the body weight excluding the legs, which would be about 72 lbs. in a 12 stone man. This would act vertically through the head of the femur. When walking, however, the weight is borne on one leg at a time, leading to enormous forces acting at the hip joint; in the figure this can easily be seen.

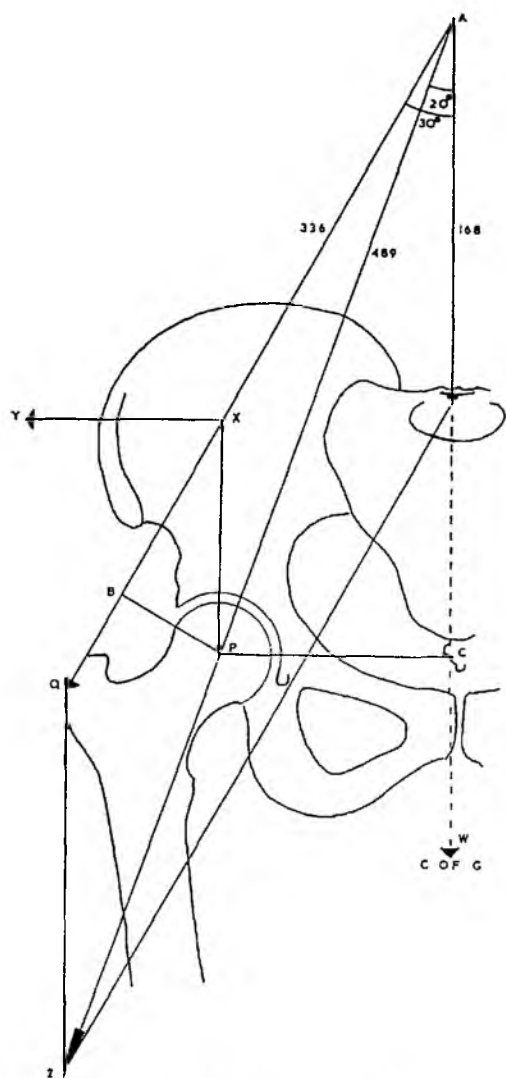
The centre of gravity passes slightly to the same side as the weight bearing hip; this leads to an adduction moment  $W \times PC$ . To balance this the abductors, gluteus medius and minimus, must exert an equal moment and because their line of action is much nearer the centre, P, the force must be correspondingly greater. In fact PC is at least twice PB (Inman 1953 gave 2.4 - 2.6) so that the muscles must achieve a force of at least twice the body weight; this means that the total load on the hip, the resultant, is almost three times the body weight, acting downwards and 20° outwards.

Balance in the antero posterior direction is controlled by gluteus maximus.

The aetiology and pathogenesis of several disease processes will now be considered in order to illustrate the importance of some of the above factors.

#### CONGENITAL DISLOCATION OF THE HIP

This disorder occurs in 15 per 10,000 live births in this country, but in countries such as Japan, North Italy and Brittany the incidence is as high as 40 per 10,000 live births. The incidence is much lower in countries where mothers carry their babies astride their backs. Girls are affected four times more frequently than boys and the left hip three times more than the right; it is bilateral in only 25% of cases. Dislocation at birth and dislocation as



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part of a general disorder, e.g. athrogryphosis, are not considered here.

The typical dislocation is not a primary developmental defect because the joint develops by cleavage of a solid block of mesoderm which is complete by the tenth week of intrauterine life.

Among the many factors suggested are hereditary and familial influences but it is not clear whether this represents a genetic predisposition to dislocation as such or merely a tendency to

predisposing factors such as placental site. Gill in 1948 suggested a disturbance of the maternal environment; perhaps after the discovery of the effects of Thalidomide this may seem a possibility. Dennis Brown (1948) postulated intra-uterine mechanical stress as a cause; pressure of the uterus on a flexed knee in a breech presentation forcing the head down and back out of the acetabulum. In 1962 Barlow produced results to suggest that the incidence was increased in breech presentation but it was not possible to say which was cause and which effect. Acetabular hypoplasia and increased anteversion of the femoral neck have both been suggested as primary factors but both are more likely to be secondary. Von Rosen showed, in 1962, that in babies with C.D.H. the pubic symphysis could be distracted twice the distance of that of a normal child; he also found an increased excretion of Oestrogens in the urine of these babies, for the first three days of life. Hence it seems possible that hormonal factors may relax ligaments which allows the mechanical stresses in the uterus to produce subluxation or dislocation and increased anteversion. Consequent upon this the limbus, consisting of cartilage and a fold of capsule, turns into the joint and this together with hypertrophy of the ligamentum teres and capsule leads to difficulty in reduction. With delayed reduction hypoplasia of the acetabulum becomes apparent and the intumed limbus may calcify (Somerville 1953). After a good early reduction almost normal structure and function will be achieved. In a variable proportion of patients an epiphysitis develops probably due to interference with the blood supply to the ossific nucleus of the normal side. The pathogenesis is not clear but the long intracartilagenous course of the vessels would render them liable to compression in the Frog or Bachelor positions used for reduction.

#### PERTHES' DISEASE

Between the ages of 3 and 16, but especially 4 and 10 years, children are at risk to Perthes' disease; it is 2 or 3 times more common in boys and bilateral in about 10% of cases. It is more common than C.D.H. but its aetiology and treatment are subjects of great mystery. Hereditary and familial influences have been suggested but are not generally thought to be important; likewise infection, trauma and hormonal factors have been suggested. The most acceptable theories implicate vascular disturbances leading to an avascular necrosis, although Ratliff (1962) compared the process

with that following fracture of the neck of the femur and said that they were not the same.

At this stage in life the epiphysis is dependent on the lateral epiphyseal vessels alone for its blood supply; compression of these vessels would lead to necrosis. This is supported by the fact that the process is most common at the anterior margin which is furthest from the blood supply, and that it does not occur in negroes, who have a supply from the ligamentum teres (Tructa 1959).

Experimental findings are mainly extrapolation from animals because of the innocent nature of the condition; in general these support a loss of arterial supply as the primary event. This is followed by multiple fractures of the trabeculae, but because of the avascularity no reaction occurs except in the synovial membrane — swelling of this membrane and the ligamentum teres leading to lateral displacement of the head. If fibrosis occurs at this stage the displacement will be more marked and prolonged. The inflammatory response causes a decalcification in the area but the ossific nucleus, having no blood supply, does not take part, giving an appearance of increased radio density of the head.

From surviving tissue the repair begins and thus at this stage may be found areas of necrotic bone and of new bone; because some superficial subchondral layers of bone are supplied with nutrients through the surviving cartilage it is also possible to find areas of new bone overlying necrotic bone.

The pain caused by the inflammatory reaction around the joint causes the patient to adopt a limp in which the centre of gravity moves laterally decreasing the work demanded of gluteus medius and thus the load on the hip joint. In fact the load in this position is only the body weight and acts vertically through the femoral head; this in turn means that the load is spread over a much smaller area of the head, increasing the pressure. This immense pressure is associated with indentation of the head at every step causing trabecular fractures. During repair the pressure and the enlarged soft tissue lead to flattening of the head followed by flattening of the acetabulum if treatment is not prompt and effective.

#### SLIPPED EPIPHYSIS

Displacement of the upper femoral epiphysis is a not uncommon problem affecting boys more than girls between the ages of 12 and 15 years. At this time the adult sex hormones are just beginning to be secreted at a higher level

and this may be important. The ratio of the Growth Hormone and the Gonadotrophic Hormones appears to control the rate and duration of growth, with a fall of G.H. and increase in sex hormones occurring through puberty. A delay or fall in the production of sex hormones by the anterior pituitary which later returns to normal or continued high output of G.H. both give rise to a relative increase in the amount of G.H. The former gives a mild Fröhlich's syndrome and the latter a mild pituitary gigantism.

In 1950 Harris showed the effect of this to be a widening of the layer of cartilage cells in the epiphyseal line which is a structurally weaker zone and is rendered even weaker. Scott (1956) showed that 70% of the patients had Fröhlich-like features and 30% had signs of G.H. excess, in his series of patients.

The weakened epiphysis is then exposed to the stresses of weight bearing and of progression: the tendency to leave the epiphysis with the pelvis is increased. The pain so caused produces a limp in which the weight is transferred laterally and acts vertically on the head of the femur as described above. This change in the direction of the force greatly increases the shearing strain at the epiphyseal line, and the femur becomes more vertical, again increasing the strain; these changes act to displace the epiphysis downwards and backwards.

The displacement is not sudden but gradual usually, and in 25% of cases becomes bilateral.

#### OSTEOARTHRITIS

Osteoarthritis is the major disease of the limp in adult life and may be roughly divided into primary and secondary; the aetiology of the primary form is rather a mystery, most attempts to explain it using a secondary theory.

A normal joint can survive normal work for a hundred years, whereas an abnormal joint will show changes at an earlier age. Wolff's Law may be considered alongside this observation: just as normal function gives rise to normal structure, abnormal function may be expected to give rise to abnormal structure; thus osteoarthritis may represent a change in structure related to a limp (abnormal function) from some primary pathological change.

In the gluteus medius limp, described above, the weight of the body is seen to act on a much reduced area of the femoral head, so that in spite of reduced load there are areas of very high pressure and areas of very low pressure. This loss of the normal compression and expansion of cartilage results in decreased

nutritional supply, first in the deeper layers, and this undernourished tissue disrupts under high pressure giving rise to fibrillation and erosion. This allows a further shift of the head, accentuating the pressure differences and leading to damage to the bony articular surface. The trabeculae undergo changes to counteract the changes, becoming thickened; this requires an increase in vascularisation in a wedge shaped vascular supply area which becomes apparent radiographically. In spite of strengthening, trabecular infractions still occur and local hyperaemia denotes the start of repair processes. At the same time some trabeculae lose their blood supply, as in all fractures, and synovial fluid enters the necrotic areas giving rise to the cyst formation seen on X-ray pictures. With a loss of fine structure comes a loss of gross structure and flattening of the head,

proportional to the extent of devascularisation. The fluid trapped in the bone transmits pressure to the cyst walls causing a reactive schlerosis.

Strange suggests that the size of the head and acetabulum now increases in an attempt to reduce the pressure; this is the process of lipping and osteophyte formation which Harrison et al (1953) considered to be primarily due to increased vascularisation. Harrison et al considered osteoarthritis to be primarily a vascular reaction to degeneration of articular cartilage and that abnormalities resulting, e.g. osteophytes, are evidence of persistent attempt at repair.

The theories presented above are really all involving a secondary mechanism though a primary disease process may not always be obvious.

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### Dubious Philosophy?

"The reader will find that the opium-eater boasteth himself to be a philosopher; and accordingly, that the phantasmagoria of his dreams (waking or sleeping, day-dreams or night-dreams) is suitable to one who in that character,

HUMANI NIHIL A SE ALIENUM PUTAT.

The true philosopher, de Quincey affirms, possesses "that constitution of faculties, in short, which (amongst all the generations of men that from the beginning of time have deployed into life, as it were, upon this planet), our English poets have possessed in the highest degree, — and Scottish professors in the lowest."

from the Society's copy of  
 "Confessions of an English Opium-Eater"  
 (1853 ed.) by Thomas de Quincey.